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SIGNAL CHAIN for the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS)

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ABSTRACT

The AVIRIS instrument has a separate dedicated analog signal processing chain for each of its four spectrometers. The signal chains amplify low-level focal-plane line array signals (5-10 mV full-scale span) in the presence of larger multiplexing signals (~ 150 mV) providing the data handling system a ten-bit digital word (for each spectrometer) each 1.3 µs. This signal chain provides automatic correction for the line array dark signal nonuniformity (which can approach the full-scale signal span).

1. INTRODUCTION

The Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) is a collection of four spectrometers monitoring the spectrum over the range from 0.4 to 2.45 µm. In each spectrometer the input optical signals are converted into electrical signals by a line array focal-plane assembly (FPA) shown schematically in Fig. 1. Details of the FPAs are discussed in a companion paper.[1]

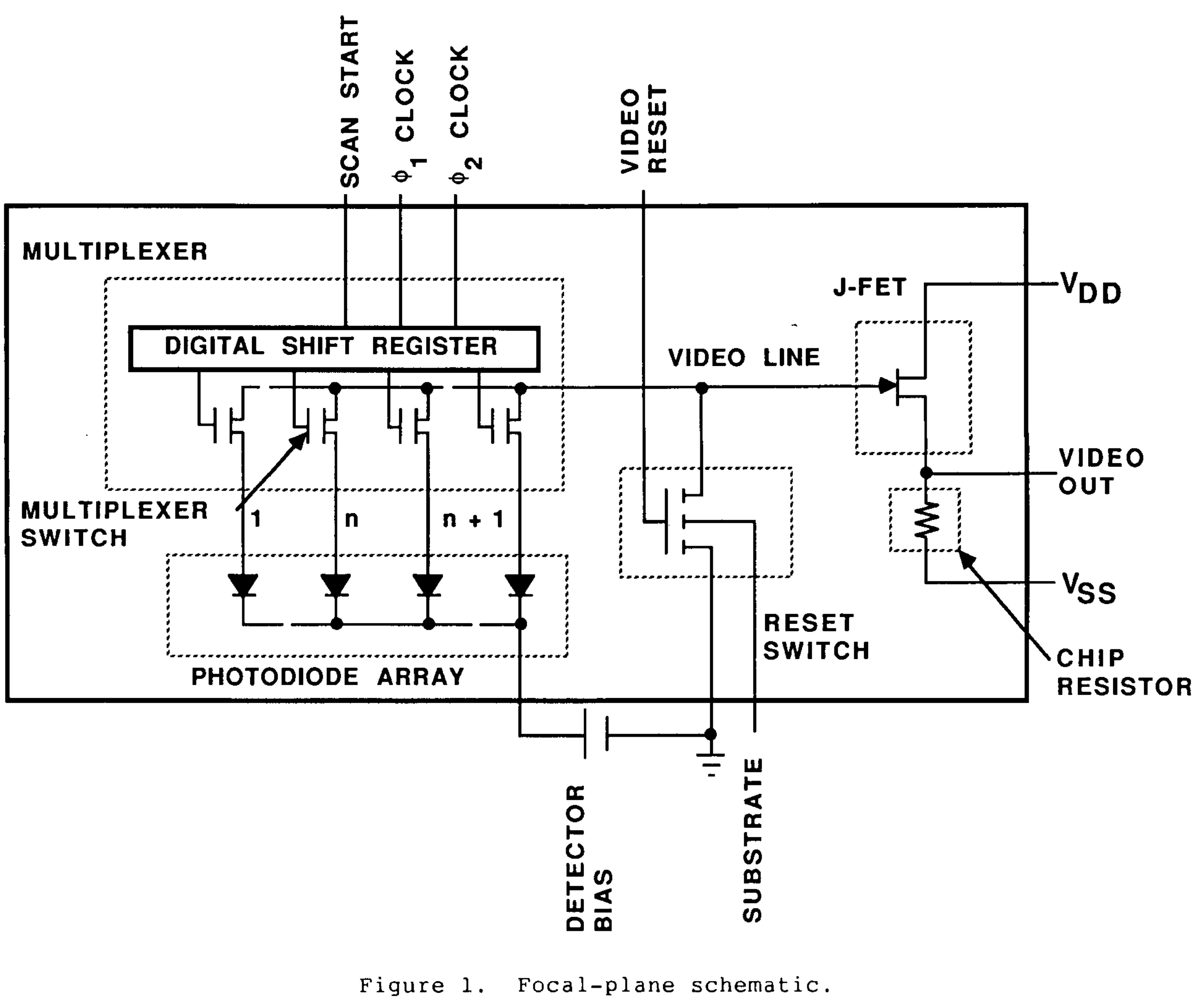

Figure 1. Focal-plane schematic.

The FPA consists of a line array of detectors (32 detector elements for the silicon visible array and 64 detector elements for each of the indium antimonide infrared arrays), a shift register/multiplexer (used to access each detector in sequence), a biasing/reset MOSFET switch and a video output junction FET (JFET) buffer amplifier. When a detector is selected, its output is switched onto the gate of the JFET follower. The follower output provides the low-impedance FPA output signal (VIDEO OUT).

The video signal is shown in Fig. 2. As each detector is selected, the signal (positive-going from the dark level) is available for about 800 ns. The detector is then reset (biased) by turning on the MOSFET reset switch for about 331 ns. The reset switch is opened, and 166 ns later the multiplexer switches the next detector onto the VIDEO LINE.

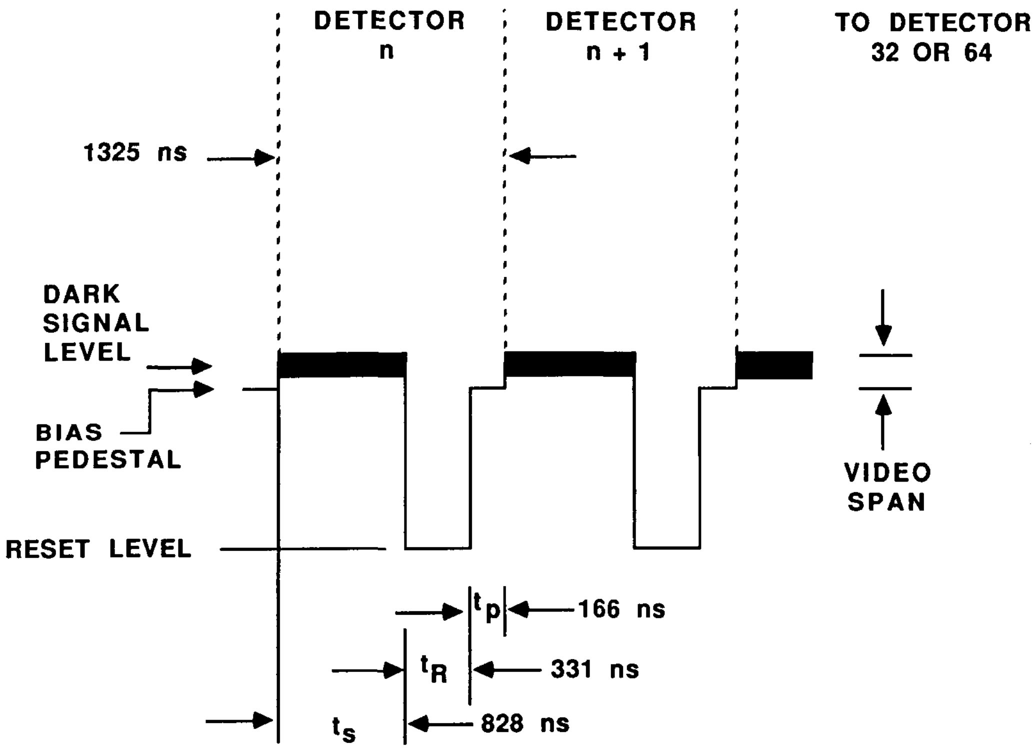

Figure 2. FPA VIDEO OUT.

Each detector requires 1325 ns to read out, reset, and switch to the next detector. For all arrays the readout timing is set up for 64 detectors and two dummy timing intervals to provide an array cycle time of about 87 μs. The array readout is synchronized by a roll-corrected signal scan-mirror position readout at the start of scan.

Quantitative values for the VIDEO OUT signal are listed in Table 1. The FPA JFET buffer provides the low output resistance. The signal span is small so that the signal chain gain must be several hundred V/V to raise the signal level high enough for analog-to-digital conversion (ADC).

Table 1. FPA Video Signal Characteristics

Parameter	Value	Units
Source resistance	300	Ω
Signal span	5 to 10	mV
Noise (~1 MHz NBW)	10 to 15	μVrms
Dark signal nonuniformity	~4	mVpp
Max Bias Pedestal (from reset level)	150	mV
Signal dc offset	~+0.2	Vdc

Because the dark signal nonuniformity is comparable to the full-scale signal span, the nonuniformity will occupy a significant portion of the ADC span unless corrected.

The bias pedestal refers to the voltage difference between the reset level and the signal level after the reset switch turns off (Fig. 2). For the small signal spans seen in

the AVIRIS instrument, the pedestal is 15 to 30 times the full scale span. The signal chain must recover from the overload within approximately 0.25 μs following the signal return to bias level.

The foregoing discussion describes the input interface for the signal chain. At the other end of the signal chain is the interface with the data handling system. The basic requirement is to encode the signal span into ten binary bits while preserving the signal-to-noise ratio found at the input to the signal chain.

2. THE SIGNAL CHAIN

The analog signal processing for the four spectrometers is divided into five physical locations as shown in the overall block diagram (Fig. 3). Each spectrometer has a dedicated analog signal chain which processes the FPA output (VIDEO OUT in Fig. 1).

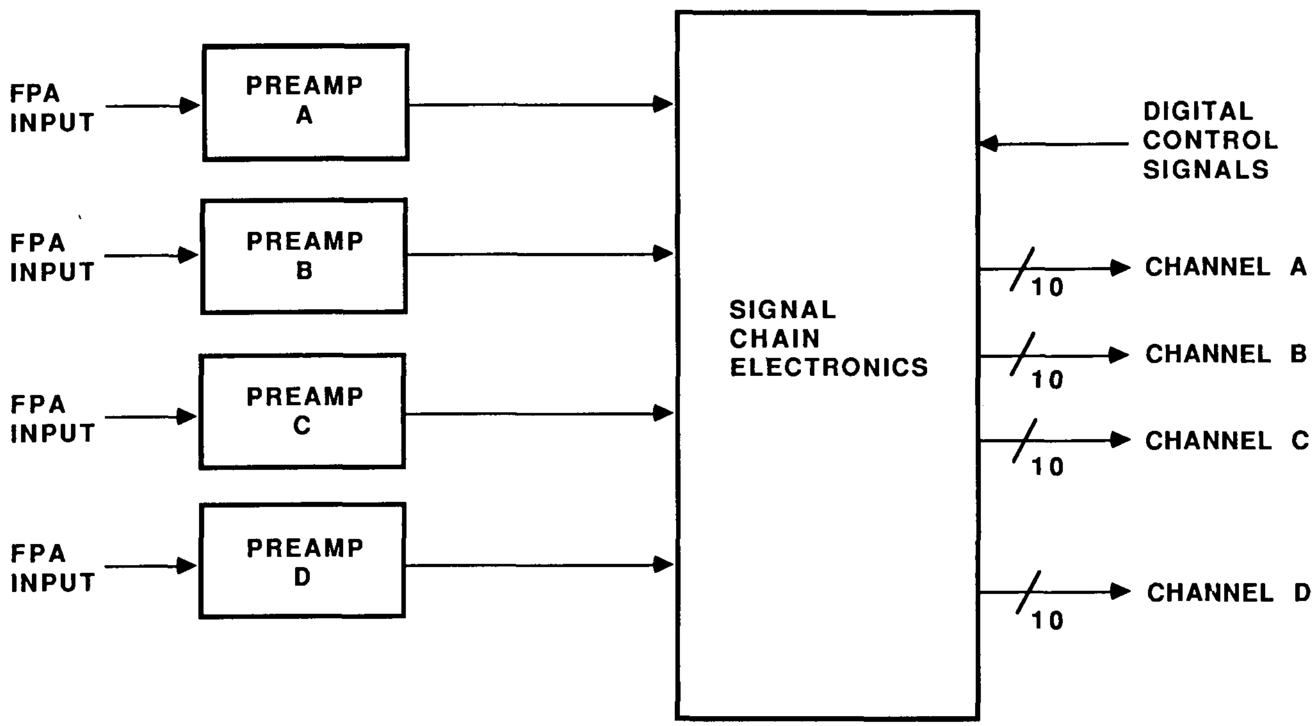

Figure 3. Analog signal processing overall block diagram.

Functionally, the signal chains do more than just amplify the detector signals. They clip the portion of the detector output not carrying signal information to prevent saturation of the signal chains. They also limit the noise bandwidth with an integrator stage and provide correction for detector nonuniformities.

The nonuniformity correction is updated at the start of the data collection run. It works by measuring the output of each of the 224 detector elements with the instrument shutter closed. These measurements are digitized to eight bits and stored in memory. As each detector element is read out during data collection, the corresponding correction measurement is recalled from memory, converted to analog form in a DAC, and subtracted from the data in analog form in the signal chain. The corrected data value is then digitized to ten bits for recording.

A preamplifier subassembly is mounted on each dewar. Each dewar houses an FPA at the optical output of each spectrometer. The preamplifier provides gain close to the FPA so that the low level VIDEO OUT signal is not exposed to interference in the instrument cable harness.

The four amplified signals are cabled to the signal chain electronics where amplification, nonuniformity correction, and integration occur. The integrated signals are digitized by four ADCs in the signal chain electronics box to provide ten-bit output words corresponding to each sampled detector measurement.

2.1. Signal processing

The preamplifier provides wideband gain (50 V/V) close to the FPA. It also limits the reset signal peaks to avoid saturation in the second amplifier stage.

Figure 4 is a block diagram for the analog electronics for one spectrometer.

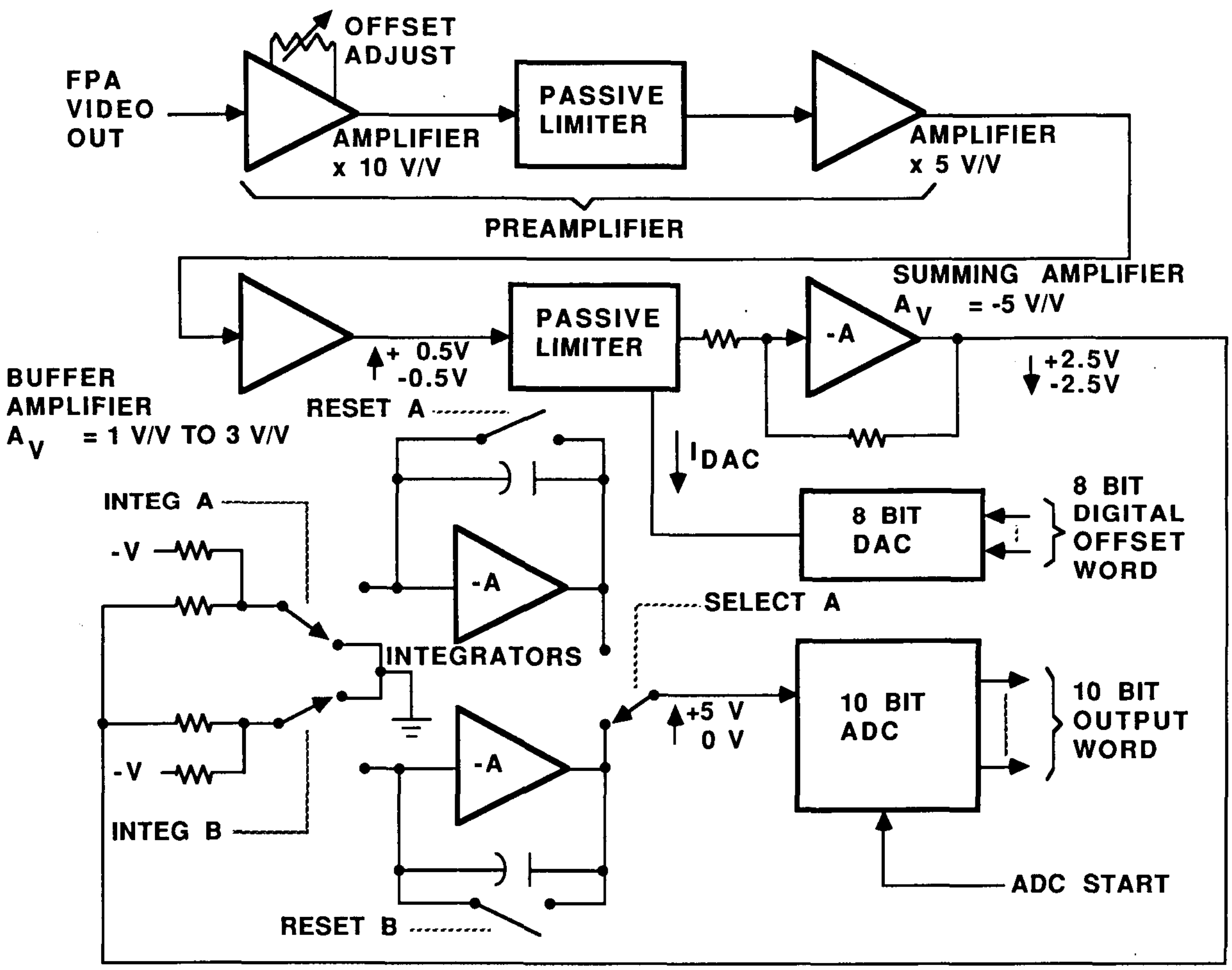

Figure 4. Analog electronics block diagram.

Each preamplifier output is cabled to the signal chain. Four sets of analog signal processing electronics are located in the signal chain electronics section, one for each spectrometer. The sets are identical except for gain tailoring to match the ADC input range with the signal available from each spectrometer.

The preamplifier output signal is received by a buffer that terminates the cable from the preamplifier and provides means for adjusting the gain in each spectrometer channel. The output of the buffer amplifier is then clipped in a fast passive limiter to remove peaks that would drive later stages into saturation. In the limiter the signal is summed with the output of an offset-correcting digital-to-analog converter (DAC) to remove detector-to-detector dark signal nonuniformity. The resulting signal is amplified to provide an analog signal to the dual integrators.

At the integrator input, the initial 5- to 10-mV signal span (from the FPA VIDEO OUT signal) has been amplified to a span of about 4 V. Guard bands (0.5 V) at the low and high ends of the signal span add 1 V to the measurement span for a total of 5 V.

The integrators set the effective noise bandwidth of the signal chain at about 600 kHz to reduce the noise contribution from the otherwise wideband signal chain. The approach employed is to operate the parallel integrators in an alternating fashion to increase the time available for analog-to-digital conversion and integrator resetting.

3. PERFORMANCE

The signal chain gains have been adjusted to values between 235 V/V and 750 V/V as required by the individual spectrometer signals. This compensates, over the instrument spectral range, for variations in the brightness of the sunlight illuminating the scene. The values used ensure that the brightest scenes viewed will not saturate the signal chains. The dark signal nonuniformity correction circuits reduce the detector-to-detector dark level variations from about 75 percent of full-scale span at worst to about 2 percent.

The measured signal chain noise performance is close to the predicted values. Combining the preamplifier equivalent input noise measurements (~ 8μVrms) and detector noise measurements (10-15 μVrms) leads us to expect an equivalent input noise range of 13 to 17 μVrms. We have obtained measurements at roughly 17 μVrms for the four spectrometer signal chains in the laboratory. However in operating situations additional noise sources were encountered so that the instrument signal-to-noise performance degraded.

The signal-to-noise (S/N) figures shown in Table 2 are for overall instrument performance. The figures account for not only the noise performance of the detectors and signal chains but all factors affecting signal level, including atmospheric transmission losses within the AVIRIS instrument and detector efficiency at each wavelength. We feel that we have identified the additional sources of excess noise measured. These problems will be addressed during the instrument upgrade this fall. The major noise source appears to be a microphonic problem with the mounting of the dewars. An additional noise contribution may be due to timing instabilities in the clocking wave forms supplied to the detectors.

Table 2. Signal-to-Noise Performance

Band	Wavelength, μm	Required S/N	Measured* S/N
A	0.7	100:1	150:1
B	1.0	---	140:1
C	1.6	---	70:1
D	2.2	50:1	30:1

*Measured performance is for integrating sphere data corrected for viewing a scene with 50 percent albedo through a standard mid-latitude midsummer atmosphere with 23-km visibility.

4. CONCLUSIONS

The AVIRIS signal chain performs well under ideal conditions, giving close to theoretical performance. It is able to extract signals within ten-bit accuracy in the face of switching transients orders of magnitude larger than a full scale signal. Compensation for dark-signal variations in individual detector elements provides correction for nonuniformities approaching the full-scale signal span.

Although noise performance for the instrument is currently below expectations (due largely to microphonics in the dewars), the signal chain is producing usable science data. The S/N specification at long wavelengths is set by the requirement to detect the kaolinite doublet. The doublet has been clearly identified in data taken to date.

5. ACKNOWLEDGMENTS

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6. REFERENCE

1. G. C. Bailey, "Visible and infrared linear detector arrays for the Airborne Visible/Infrared Imaging Spectrometer," Proceedings of the SPIE meeting held in San Diego, California, August 16-21, 1987.

Figure 5 shows the integrator timing. The total time required by each detector is 1325 ns. The detector video signal is available for 828 ns. In the first 414 ns, the signal chain settles to the new analog output voltage. For illustration the signal amplitude is exaggerated and shown increasing with each successive detector. During the next 414 ns, the input of one integrator (for example, A) is connected to the video signal.

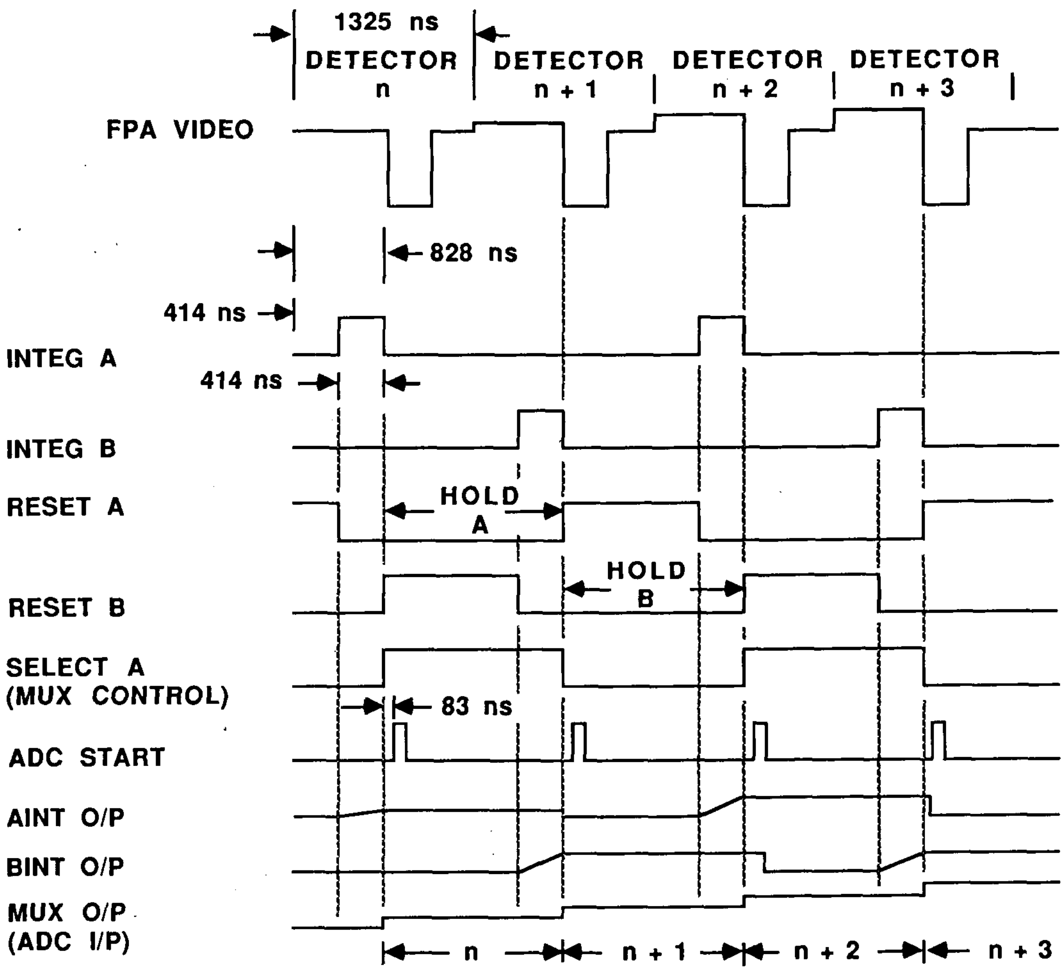

Figure 5. Integrator timing.

When the integration is completed, the ADC input switch connects the integrator A output to the ADC input. During the interval between the falling edge of INTGA and the rising edge of RESET A, the A integrator is used as a "hold" amplifier for the ADC input. The falling edge of the ADC START pulse initiates analog-to-digital conversion 166 ns later. The conversion process is completed in 900 ns maximum while the A integrator remains in the "hold" mode. The conversion is therefore complete 1166 ns after the end of integration and the ADC is ready to convert the B integrator signal. The ten-bit word resulting from the conversion is fed to the data handling system.

We noted earlier that the signal is summed with the output of an offset-correcting eight-bit DAC (Fig. 4) at the input of the summing amplifier. The purpose of this summation is to correct for the array dark signal nonuniformity and to place the dark signals near the bottom of the signal span.

The dark signal correction technique consists of storing the most significant eight bits of the ADC outputs during a special dark calibration each time the recorder is started. The stored values are used to correct the dark signal offset on a detector-element-by-detector-element basis. In addition a fixed offset is added to the signal to keep the corrected dark signal on scale.

Following each mirror scan line, the value of the corrected dark signal is measured so that drifts in the dark signal can be removed during later processing on the ground.